FIG. 1

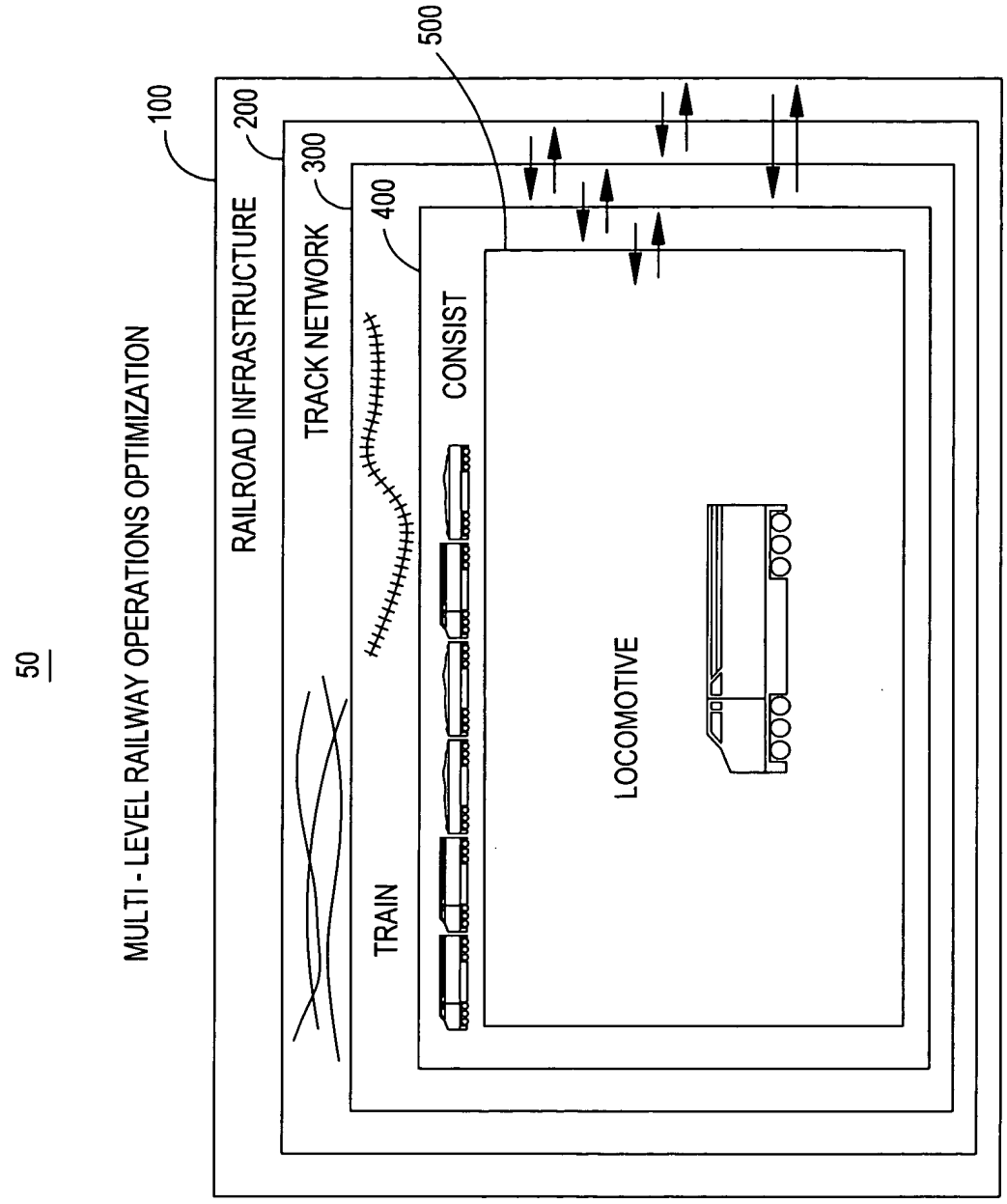

50
MULTI - LEVEL RAILWAY OPERATIONS OPTIMIZATION
100
RAILROAD INFRASTRUCTURE
200
TRACK NETWORK
300
400
CONSIST
500
TRAIN
LOCOMOTIVE

FIG. 2

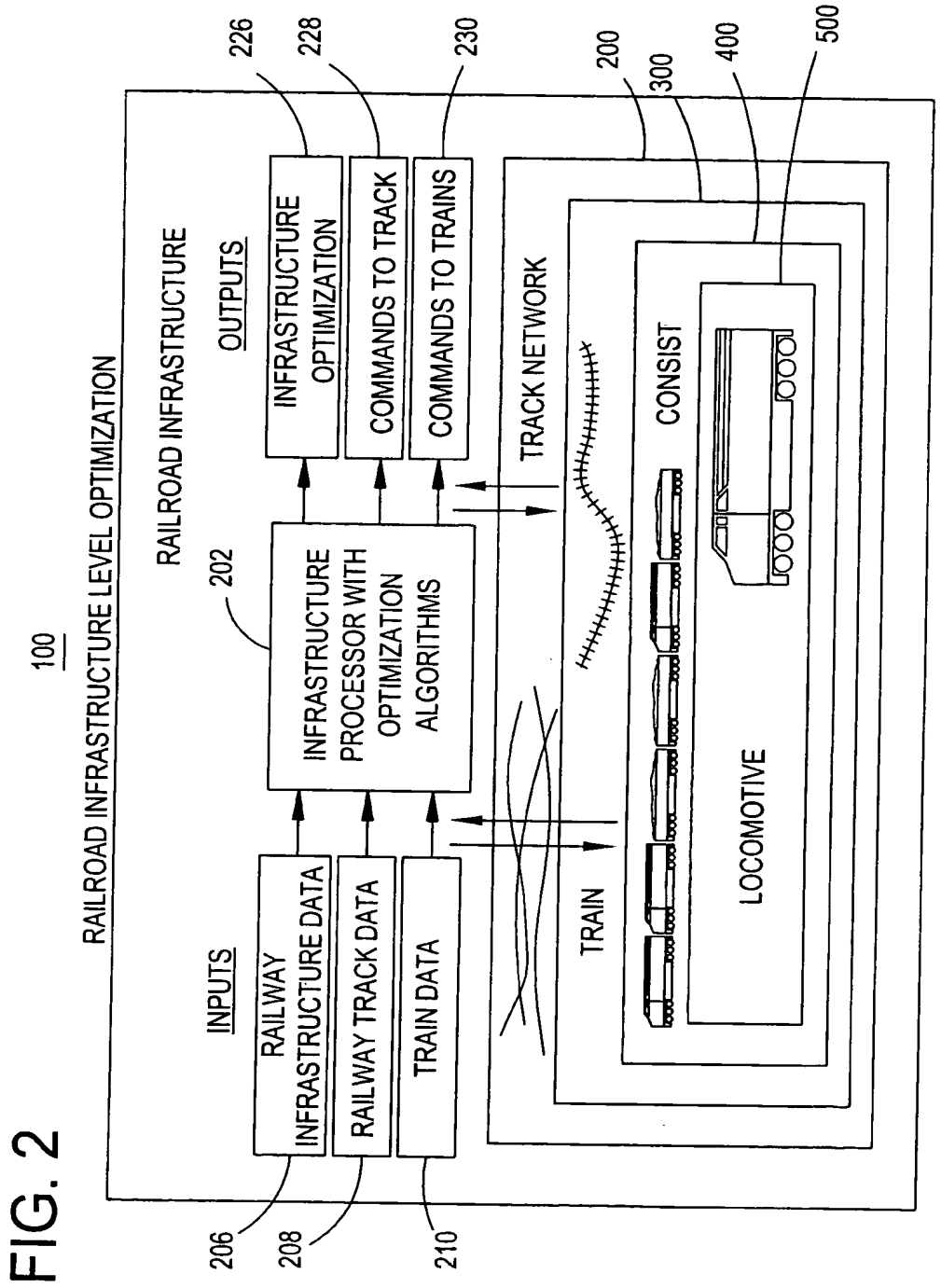

100
RAILROAD INFRASTRUCTURE LEVEL OPTIMIZATION
RAILROAD INFRASTRUCTURE
INPUTS
OUTPUTS
RAILWAY INFRASTRUCTURE DATA
RAILWAY TRACK DATA
TRAIN DATA
INFRASTRUCTURE PROCESSOR WITH OPTIMIZATION ALGORITHMS
INFRASTRUCTURE OPTIMIZATION
COMMANDS TO TRACK
COMMANDS TO TRAINS
TRACK NETWORK
TRAIN
CONSIST
LOCOMOTIVE
202
206
208
210
226
228
230
200
300
400
500

FIG. 3

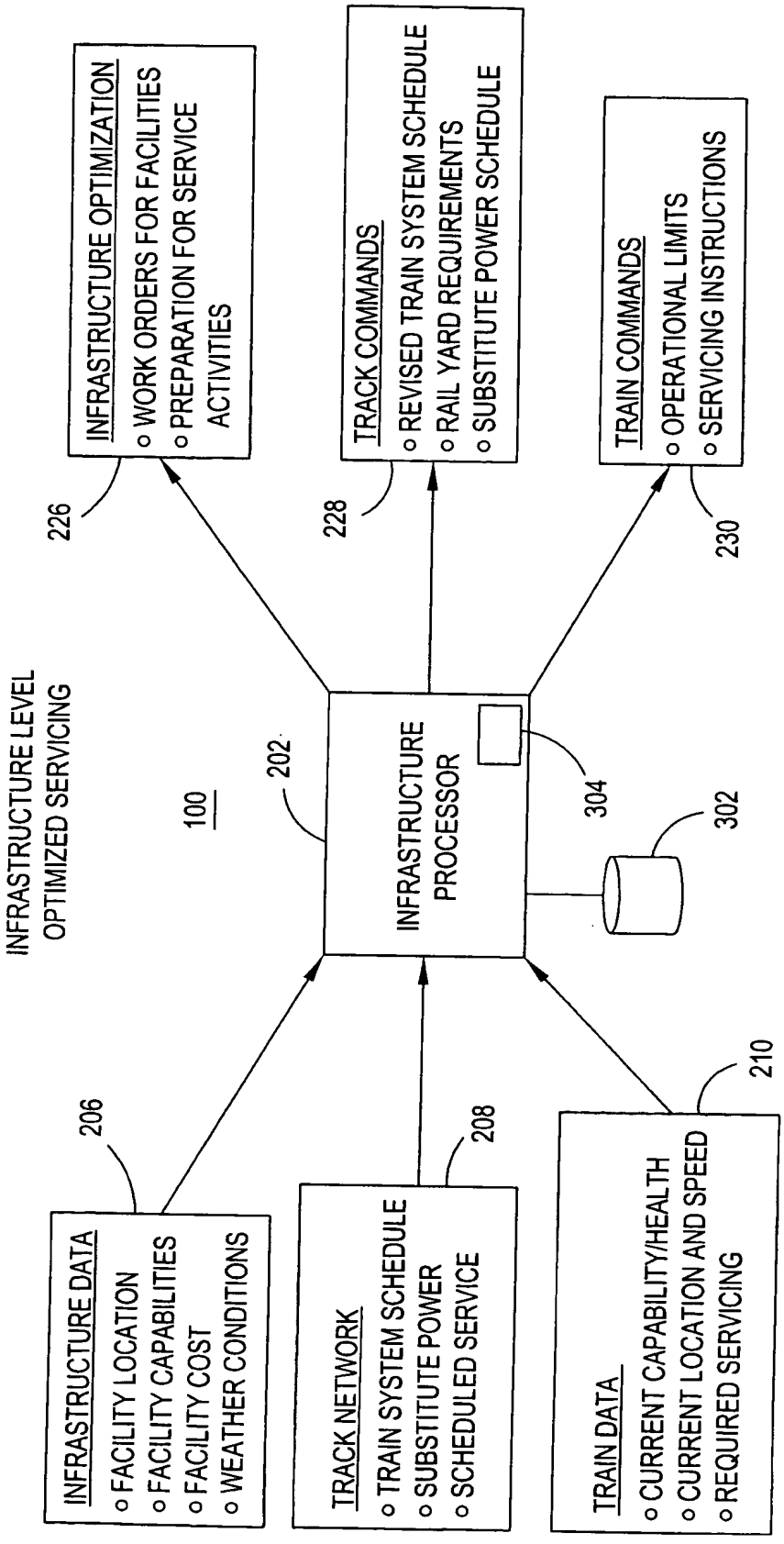

INFRASTRUCTURE LEVEL OPTIMIZED SERVICING
100
INFRASTRUCTURE PROCESSOR
202
304
302
INFRASTRUCTURE DATA
o FACILITY LOCATION
o FACILITY CAPABILITIES
o FACILITY COST
o WEATHER CONDITIONS
206
TRACK NETWORK
o TRAIN SYSTEM SCHEDULE
o SUBSTITUTE POWER
o SCHEDULED SERVICE
208
TRAIN DATA
o CURRENT CAPABILITY/HEALTH
o CURRENT LOCATION AND SPEED
o REQUIRED SERVICING
210
INFRASTRUCTURE OPTIMIZATION
o WORK ORDERS FOR FACILITIES
o PREPARATION FOR SERVICE ACTIVITIES
226
TRACK COMMANDS
o REVISED TRAIN SYSTEM SCHEDULE
o RAIL YARD REQUIREMENTS
o SUBSTITUTE POWER SCHEDULE
228
TRAIN COMMANDS
o OPERATIONAL LIMITS
o SERVICING INSTRUCTIONS
230

FIG. 4

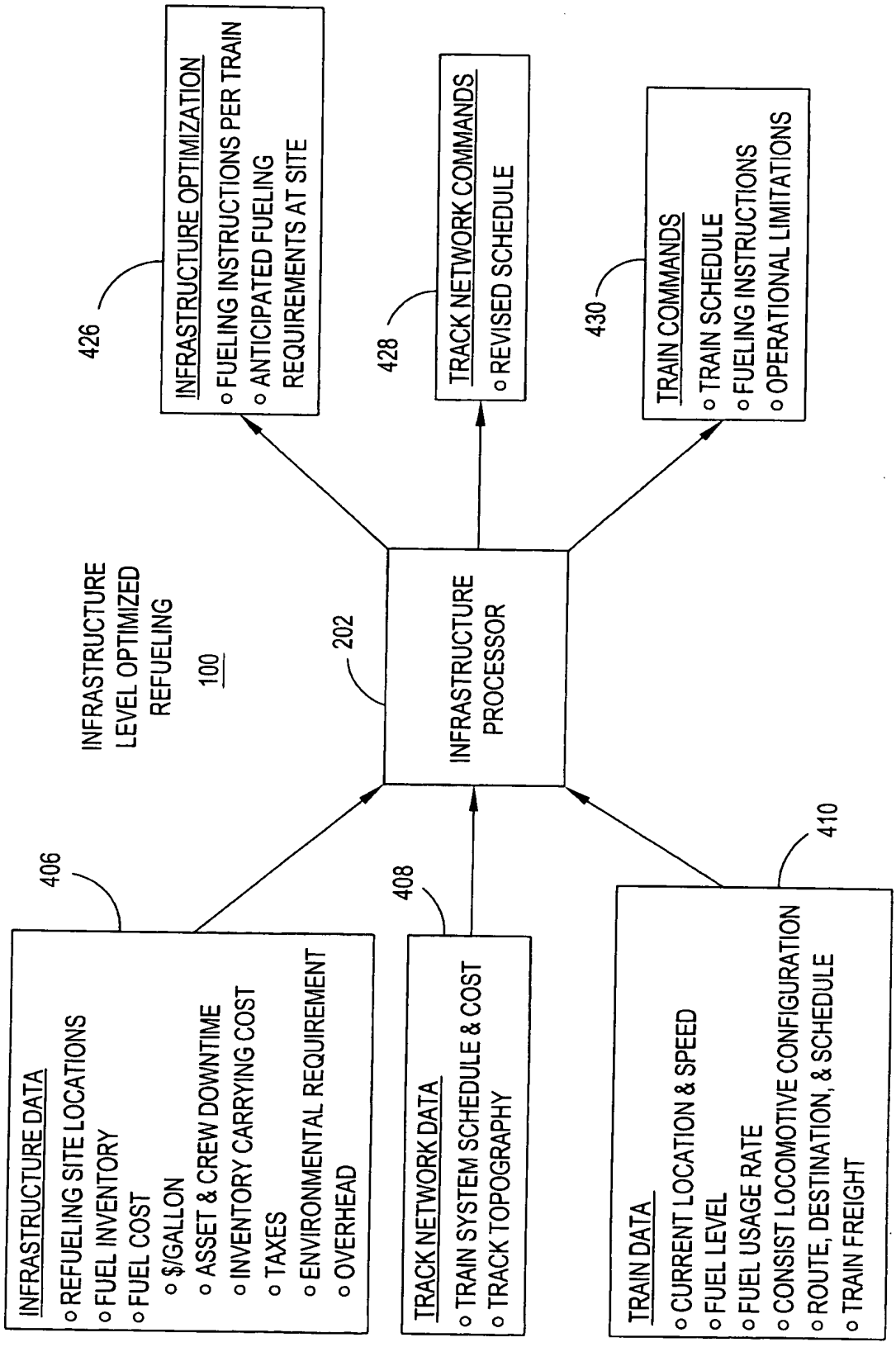

INFRASTRUCTURE LEVEL OPTIMIZED REFUELING
100
INFRASTRUCTURE PROCESSOR
202
INFRASTRUCTURE DATA
REFUELING SITE LOCATIONS
FUEL INVENTORY
FUEL COST
$/GALLON
ASSET & CREW DOWNTIME
INVENTORY CARRYING COST
TAXES
ENVIRONMENTAL REQUIREMENT
OVERHEAD
406
TRACK NETWORK DATA
TRAIN SYSTEM SCHEDULE & COST
TRACK TOPOGRAPHY
408
TRAIN DATA
CURRENT LOCATION & SPEED
FUEL LEVEL
FUEL USAGE RATE
CONSIST LOCOMOTIVE CONFIGURATION
ROUTE, DESTINATION, & SCHEDULE
TRAIN FREIGHT
410
INFRASTRUCTURE OPTIMIZATION
FUELING INSTRUCTIONS PER TRAIN
ANTICIPATED FUELING REQUIREMENTS AT SITE
426
TRACK NETWORK COMMANDS
REVISED SCHEDULE
428
TRAIN COMMANDS
TRAIN SCHEDULE
FUELING INSTRUCTIONS
OPERATIONAL LIMITATIONS
430

FIG. 5

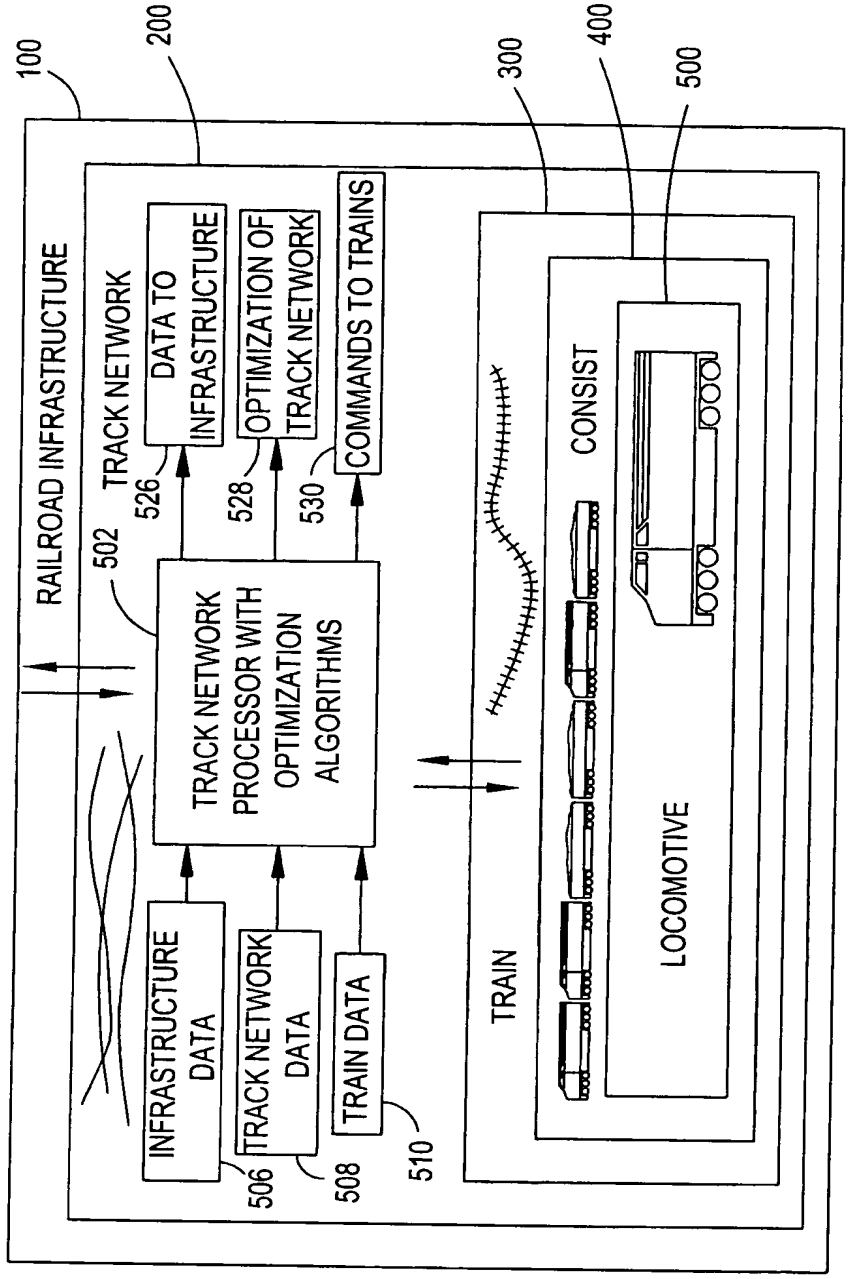

50
RAILROAD TRACK NETWORK LEVEL OPTIMIZATION
100
RAILROAD INFRASTRUCTURE
200
TRACK NETWORK
502
TRACK NETWORK PROCESSOR WITH OPTIMIZATION ALGORITHMS
526
DATA TO INFRASTRUCTURE
528
OPTIMIZATION OF TRACK NETWORK
530
COMMANDS TO TRAINS
INFRASTRUCTURE DATA
506
TRACK NETWORK DATA
508
TRAIN DATA
510
300
TRAIN
400
CONSIST
500
LOCOMOTIVE

FIG. 6

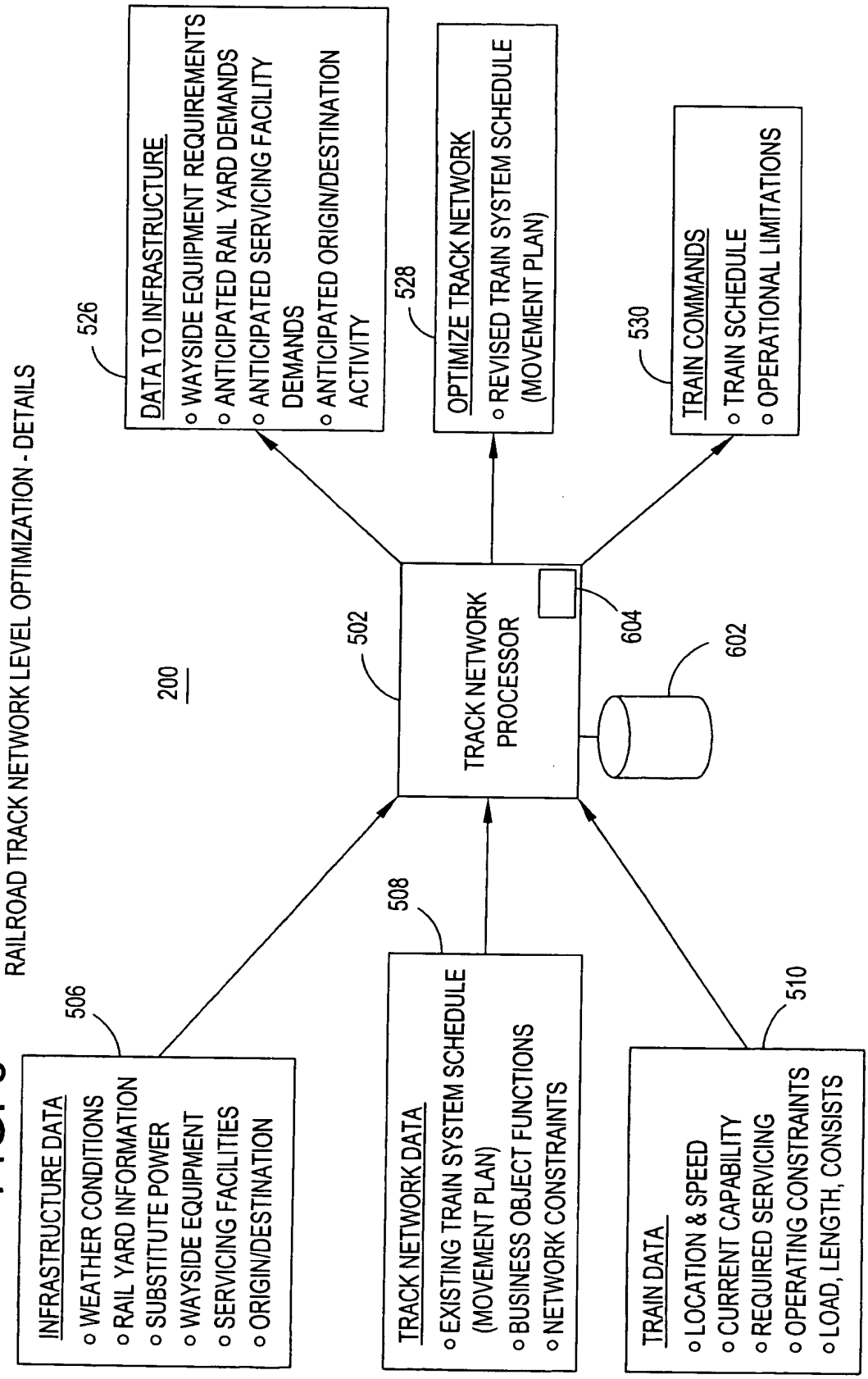
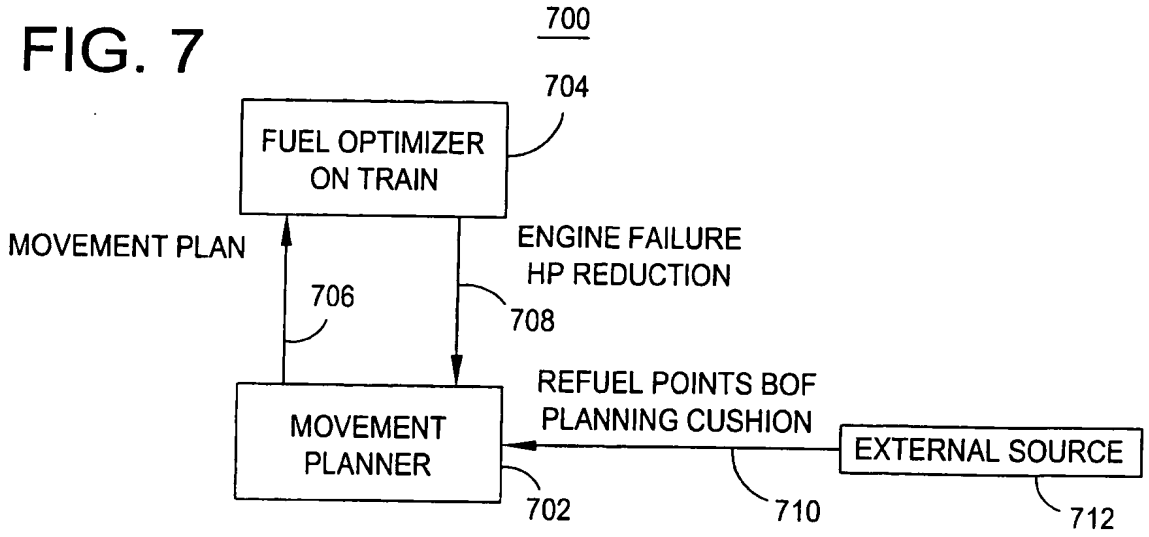
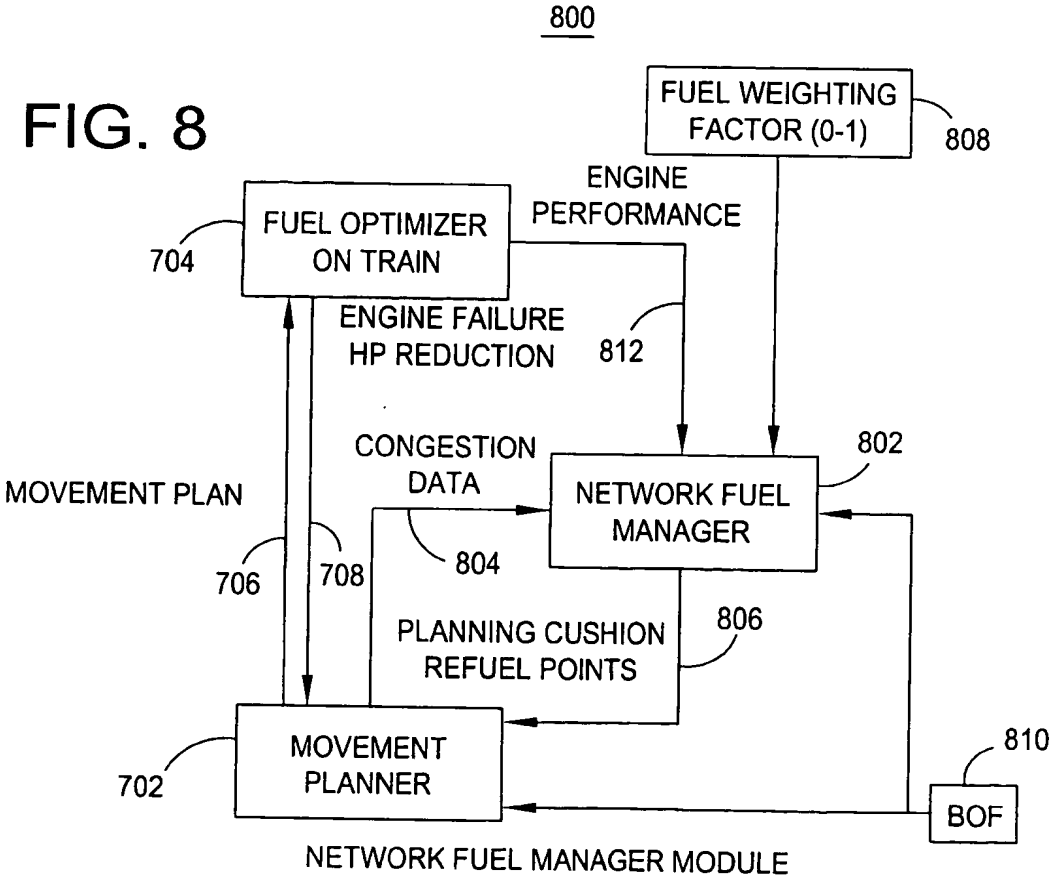

RAILROAD TRACK NETWORK LEVEL OPTIMIZATION - DETAILS
200
INFRASTRUCTURE DATA
o WEATHER CONDITIONS
o RAIL YARD INFORMATION
o SUBSTITUTE POWER
o WAYSIDE EQUIPMENT
o SERVICING FACILITIES
o ORIGIN/DESTINATION
506
TRACK NETWORK DATA
o EXISTING TRAIN SYSTEM SCHEDULE (MOVEMENT PLAN)
o BUSINESS OBJECT FUNCTIONS
o NETWORK CONSTRAINTS
508
TRAIN DATA
o LOCATION & SPEED
o CURRENT CAPABILITY
o REQUIRED SERVICING
o OPERATING CONSTRAINTS
o LOAD, LENGTH, CONSISTS
510
502
TRACK NETWORK PROCESSOR
604
602
DATA TO INFRASTRUCTURE
o WAYSIDE EQUIPMENT REQUIREMENTS
o ANTICIPATED RAIL YARD DEMANDS
o ANTICIPATED SERVICING FACILITY DEMANDS
o ANTICIPATED ORIGIN/DESTINATION ACTIVITY
526
OPTIMIZE TRACK NETWORK
o REVISED TRAIN SYSTEM SCHEDULE (MOVEMENT PLAN)
528
TRAIN COMMANDS
o TRAIN SCHEDULE
o OPERATIONAL LIMITATIONS
530

FIG. 7



INTERFACE TRAIN LEVEL TO MOVEMENT PLANNER

FIG. 8



NETWORK FUEL MANAGER MODULE

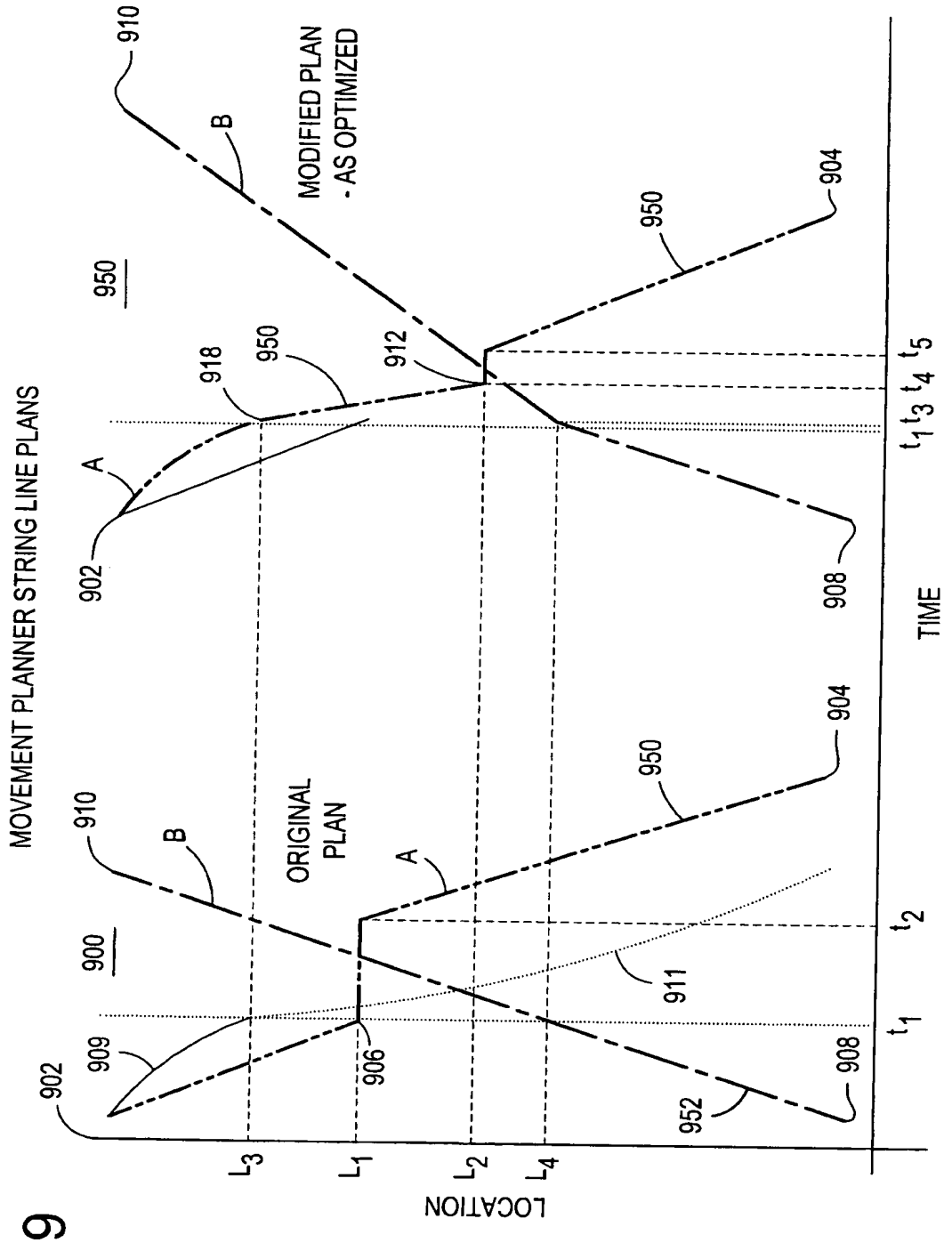

MOVEMENT PLANNER STRING LINE PLANS
MODIFIED PLAN
- AS OPTIMIZED
ORIGINAL
PLAN
950
900
910
B
A
902
909
906
911
912
918
904
908
952
LOCATION
TIME
L_3
L_1
L_2
L_4
t_1
t_2
t_3
t_4
t_5

FIG. 9

FIG. 10

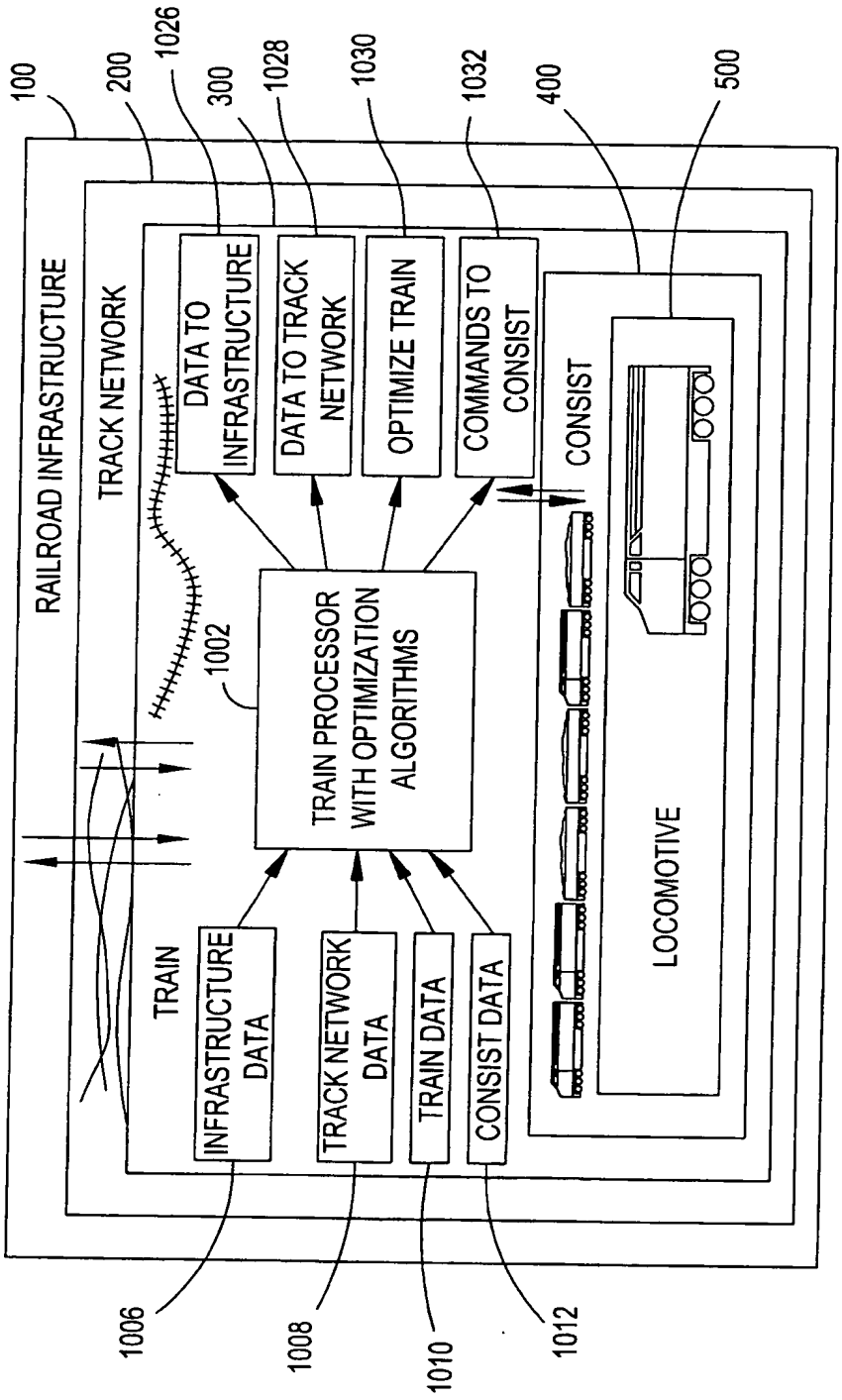

50
TRAIN LEVEL OPTIMIZATION
100
RAILROAD INFRASTRUCTURE
200
TRACK NETWORK
300
TRAIN
1002
1006
INFRASTRUCTURE DATA
1008
TRACK NETWORK DATA
1010
TRAIN DATA
1012
CONSIST DATA
TRAIN PROCESSOR WITH OPTIMIZATION ALGORITHMS
1026
DATA TO INFRASTRUCTURE
1028
DATA TO TRACK NETWORK
1030
OPTIMIZE TRAIN
1032
COMMANDS TO CONSIST
400
CONSIST
500
LOCOMOTIVE

FIG.11

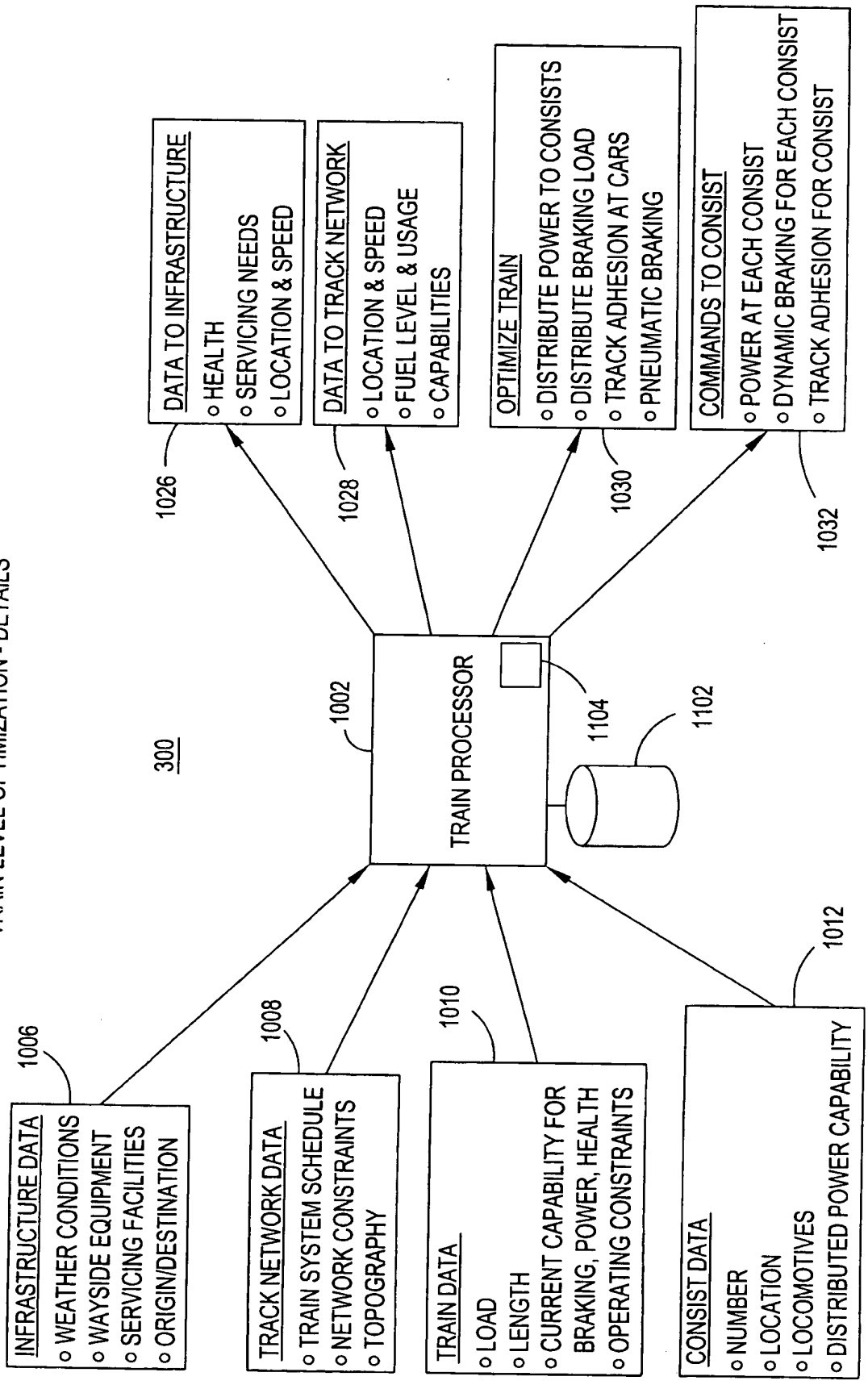

TRAIN LEVEL OPTIMIZATION - DETAILS
300
TRAIN PROCESSOR
1002
1104
1102
INFRASTRUCTURE DATA
o WEATHER CONDITIONS
o WAYSIDE EQUIPMENT
o SERVICING FACILITIES
o ORIGIN/DESTINATION
1006
TRACK NETWORK DATA
o TRAIN SYSTEM SCHEDULE
o NETWORK CONSTRAINTS
o TOPOGRAPHY
1008
TRAIN DATA
o LOAD
o LENGTH
o CURRENT CAPABILITY FOR BRAKING, POWER, HEALTH
o OPERATING CONSTRAINTS
1010
CONSIST DATA
o NUMBER
o LOCATION
o LOCOMOTIVES
o DISTRIBUTED POWER CAPABILITY
1012
DATA TO INFRASTRUCTURE
o HEALTH
o SERVICING NEEDS
o LOCATION & SPEED
1026
DATA TO TRACK NETWORK
o LOCATION & SPEED
o FUEL LEVEL & USAGE
o CAPABILITIES
1028
OPTIMIZE TRAIN
o DISTRIBUTE POWER TO CONSISTS
o DISTRIBUTE BRAKING LOAD
o TRACK ADHESION AT CARS
o PNEUMATIC BRAKING
1030
COMMANDS TO CONSIST
o POWER AT EACH CONSIST
o DYNAMIC BRAKING FOR EACH CONSIST
o TRACK ADHESION FOR CONSIST
1032

FIG. 12

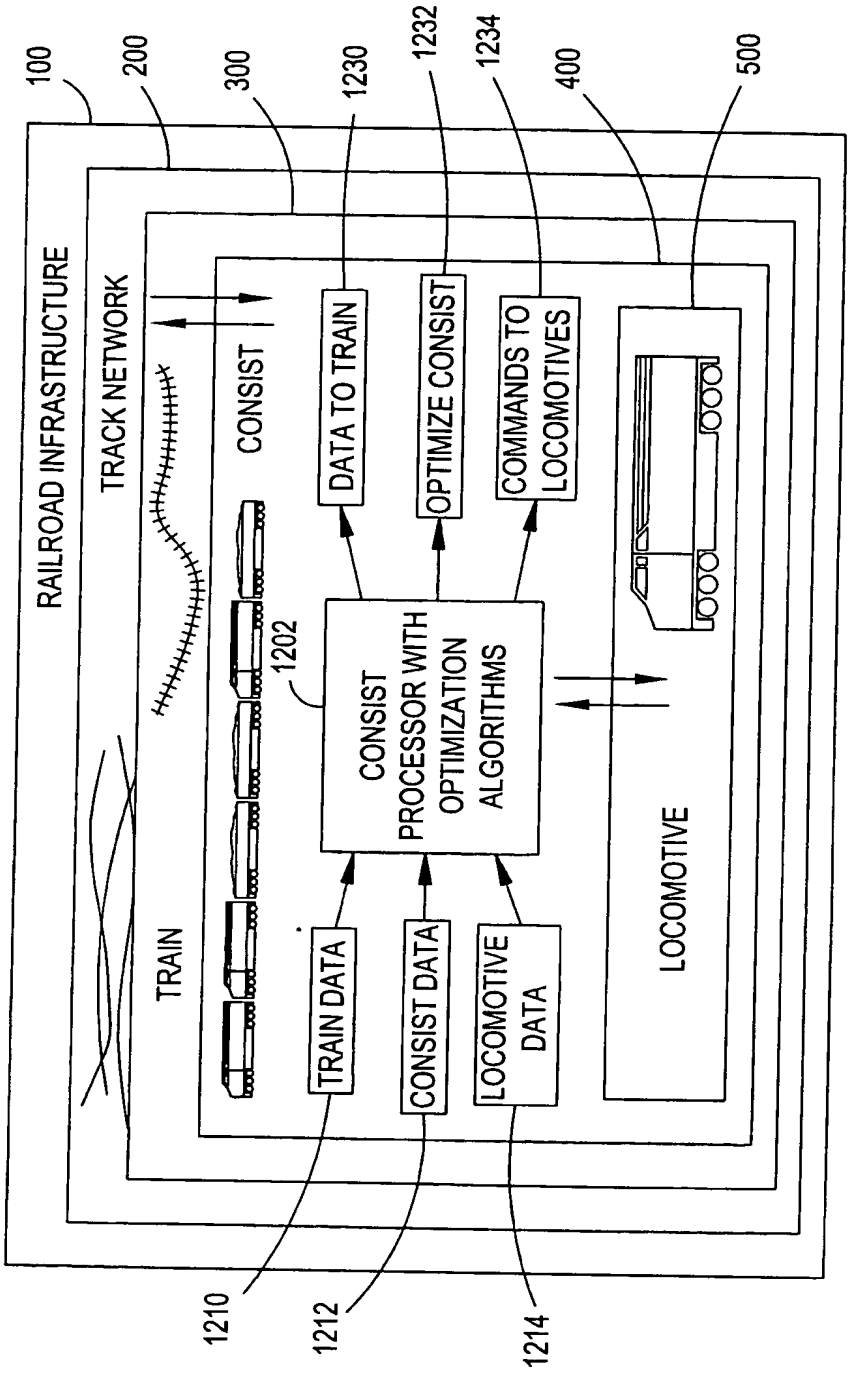

50
CONSIST LEVEL OPTIMIZATION
RAILROAD INFRASTRUCTURE
TRACK NETWORK
TRAIN
CONSIST
1202
CONSIST PROCESSOR WITH OPTIMIZATION ALGORITHMS
DATA TO TRAIN
OPTIMIZE CONSIST
COMMANDS TO LOCOMOTIVES
LOCOMOTIVE
TRAIN DATA
CONSIST DATA
LOCOMOTIVE DATA
100
200
300
1230
1232
1234
400
500
1210
1212
1214

FIG.13

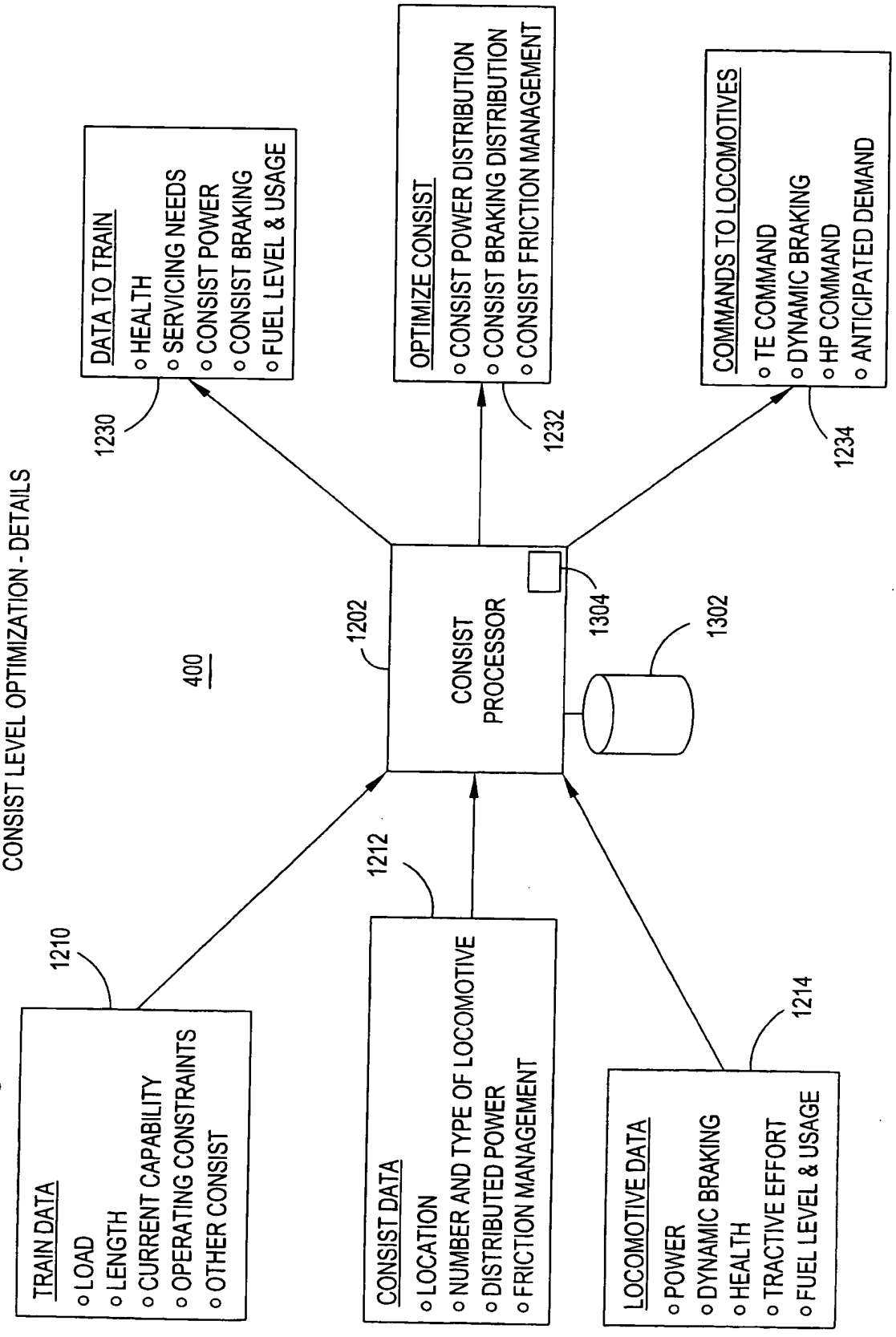

CONSIST LEVEL OPTIMIZATION - DETAILS
400
TRAIN DATA
o LOAD
o LENGTH
o CURRENT CAPABILITY
o OPERATING CONSTRAINTS
o OTHER CONSIST
1210
CONSIST DATA
o LOCATION
o NUMBER AND TYPE OF LOCOMOTIVE
o DISTRIBUTED POWER
o FRICTION MANAGEMENT
1212
LOCOMOTIVE DATA
o POWER
o DYNAMIC BRAKING
o HEALTH
o TRACTIVE EFFORT
o FUEL LEVEL & USAGE
1214
CONSIST PROCESSOR
1202
1304
1302
DATA TO TRAIN
o HEALTH
o SERVICING NEEDS
o CONSIST POWER
o CONSIST BRAKING
o FUEL LEVEL & USAGE
1230
OPTIMIZE CONSIST
o CONSIST POWER DISTRIBUTION
o CONSIST BRAKING DISTRIBUTION
o CONSIST FRICTION MANAGEMENT
1232
COMMANDS TO LOCOMOTIVES
o TE COMMAND
o DYNAMIC BRAKING
o HP COMMAND
o ANTICIPATED DEMAND
1234

FIG. 14

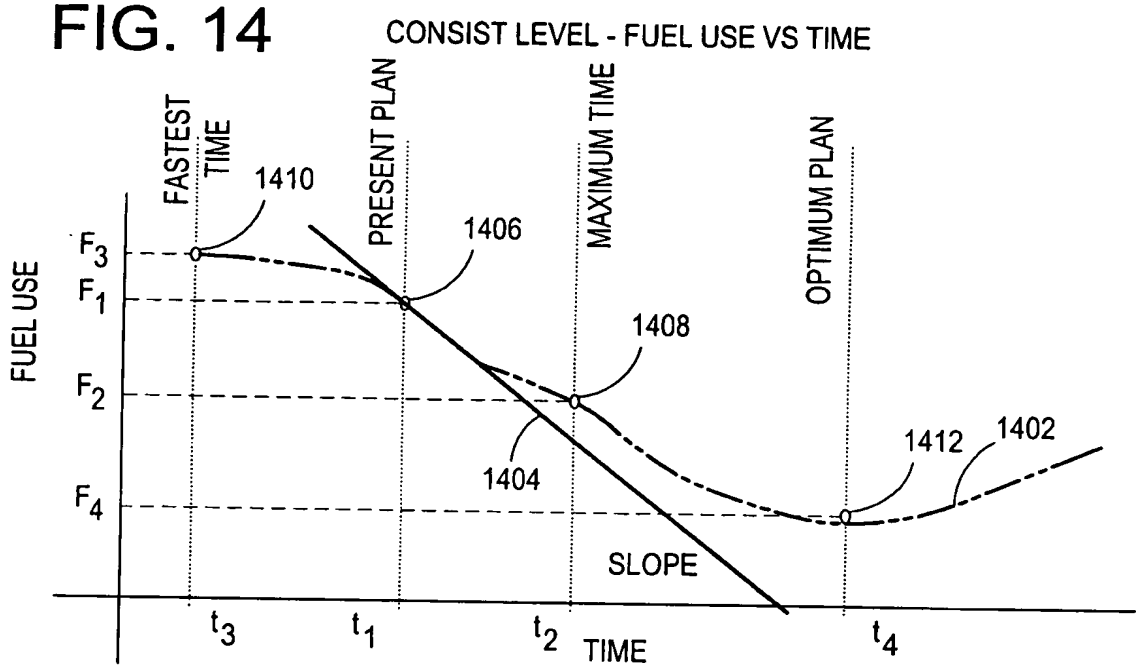

CONSIST LEVEL - FUEL USE VS TIME
FASTEST TIME
PRESENT PLAN
MAXIMUM TIME
OPTIMUM PLAN
1410
1406
1408
1412
1402
1404
FUEL USE
F3
F1
F2
F4
SLOPE
t3
t1
t2
TIME
t4

FIG. 17

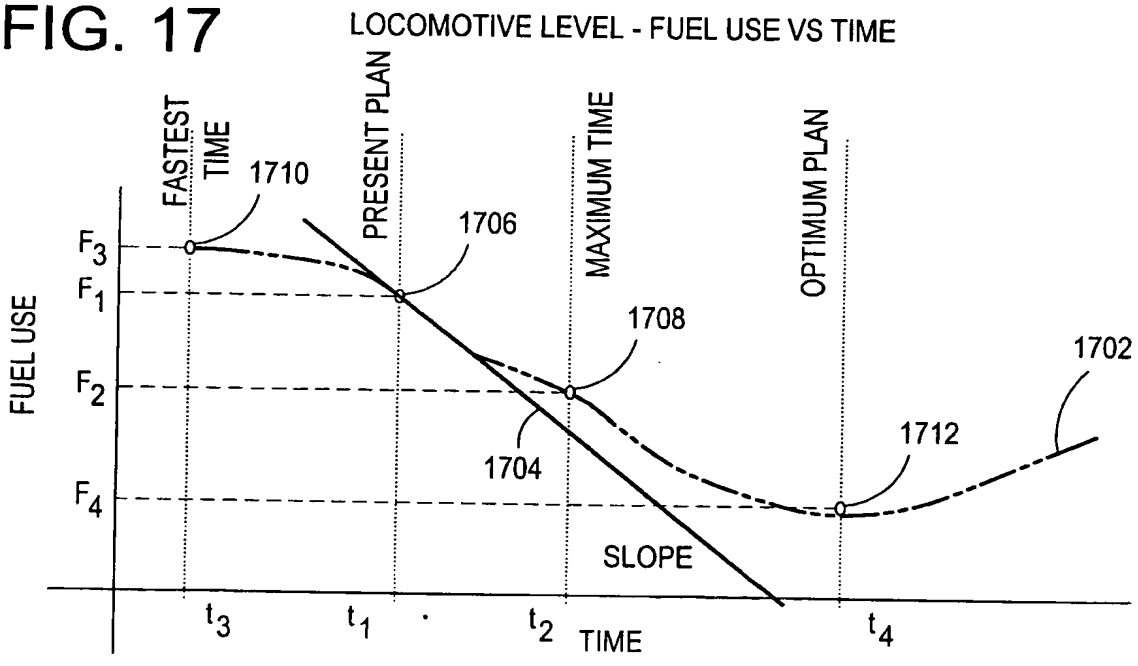

LOCOMOTIVE LEVEL - FUEL USE VS TIME
FASTEST TIME
PRESENT PLAN
MAXIMUM TIME
OPTIMUM PLAN
1710
1706
1708
1702
1712
1704
FUEL USE
F3
F1
F2
F4
SLOPE
t3
t1
t2
TIME
t4

FIG. 15

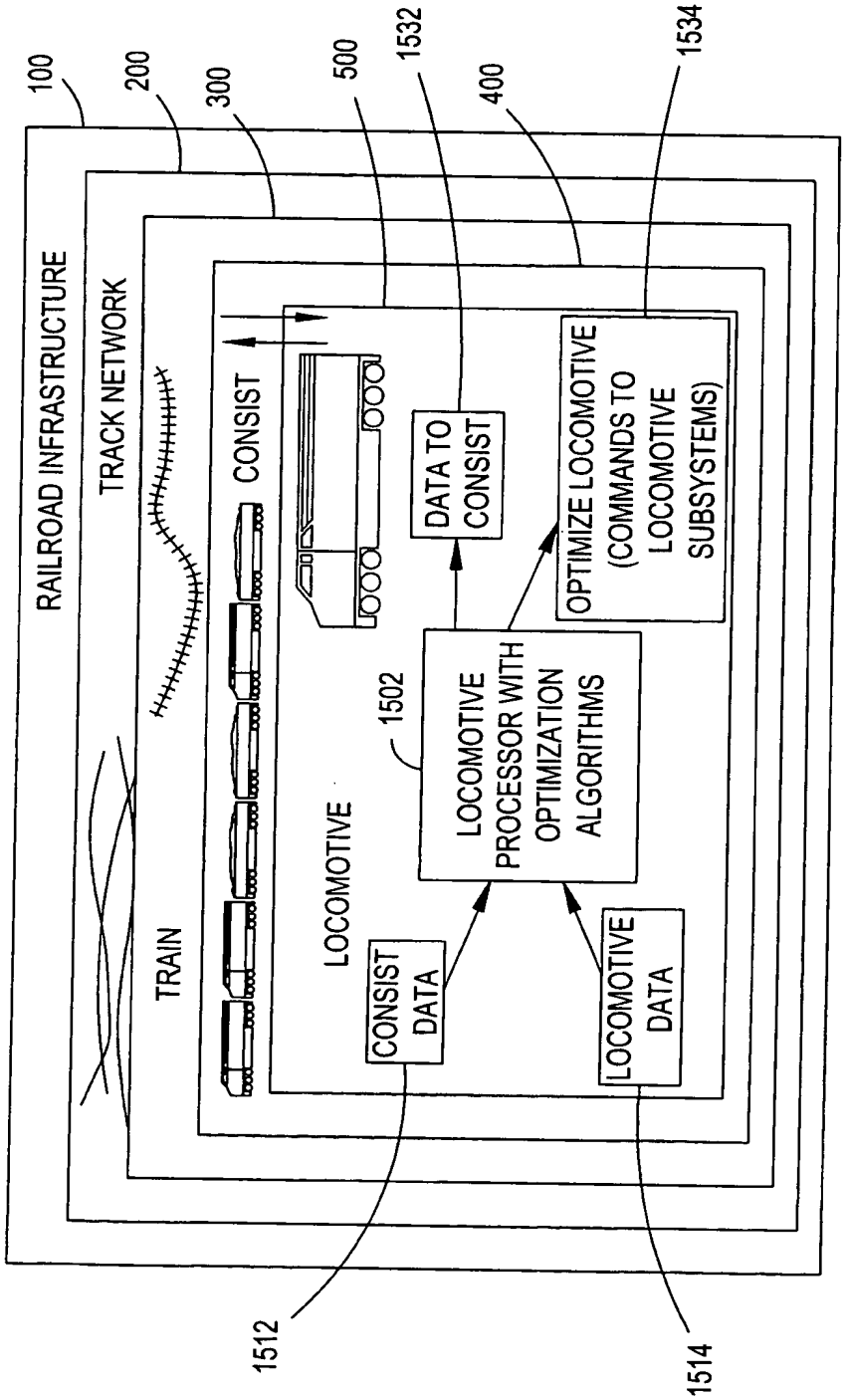

50
LOCOMOTIVE LEVEL OPTIMIZATION
100
RAILROAD INFRASTRUCTURE
200
TRACK NETWORK
300
TRAIN
CONSIST
500
LOCOMOTIVE
1502
1532
DATA TO CONSIST
400
1534
OPTIMIZE LOCOMOTIVE (COMMANDS TO LOCOMOTIVE SUBSYSTEMS)
LOCOMOTIVE PROCESSOR WITH OPTIMIZATION ALGORITHMS
CONSIST DATA
LOCOMOTIVE DATA
1512
1514

FIG.16

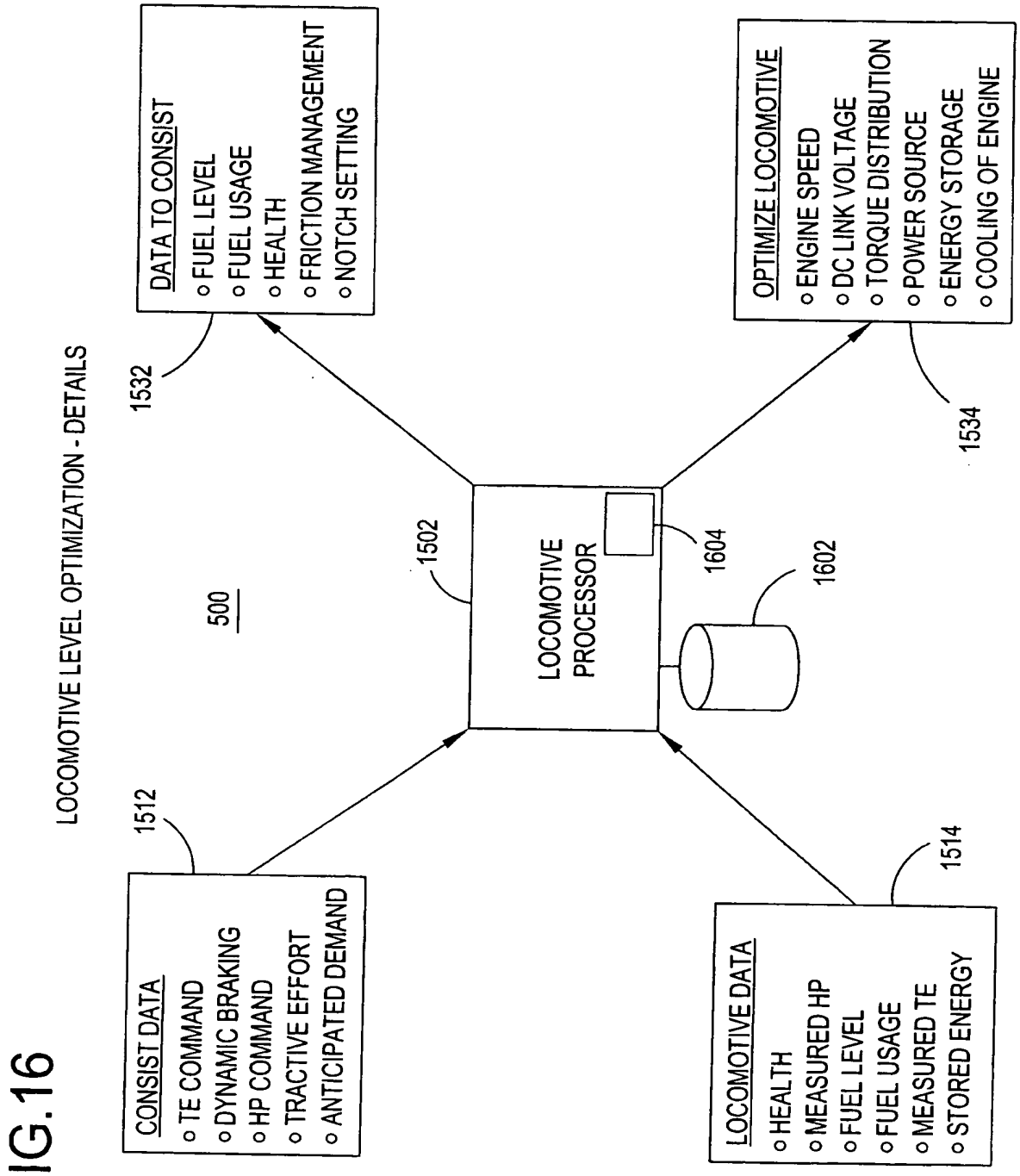

LOCOMOTIVE LEVEL OPTIMIZATION - DETAILS
500
1502
LOCOMOTIVE PROCESSOR
1604
1602
1512
CONSIST DATA
o TE COMMAND
o DYNAMIC BRAKING
o HP COMMAND
o TRACTIVE EFFORT
o ANTICIPATED DEMAND
1532
DATA TO CONSIST
o FUEL LEVEL
o FUEL USAGE
o HEALTH
o FRICTION MANAGEMENT
o NOTCH SETTING
1514
LOCOMOTIVE DATA
o HEALTH
o MEASURED HP
o FUEL LEVEL
o FUEL USAGE
o MEASURED TE
o STORED ENERGY
1534
OPTIMIZE LOCOMOTIVE
o ENGINE SPEED
o DC LINK VOLTAGE
o TORQUE DISTRIBUTION
o POWER SOURCE
o ENERGY STORAGE
o COOLING OF ENGINE

FIG. 18

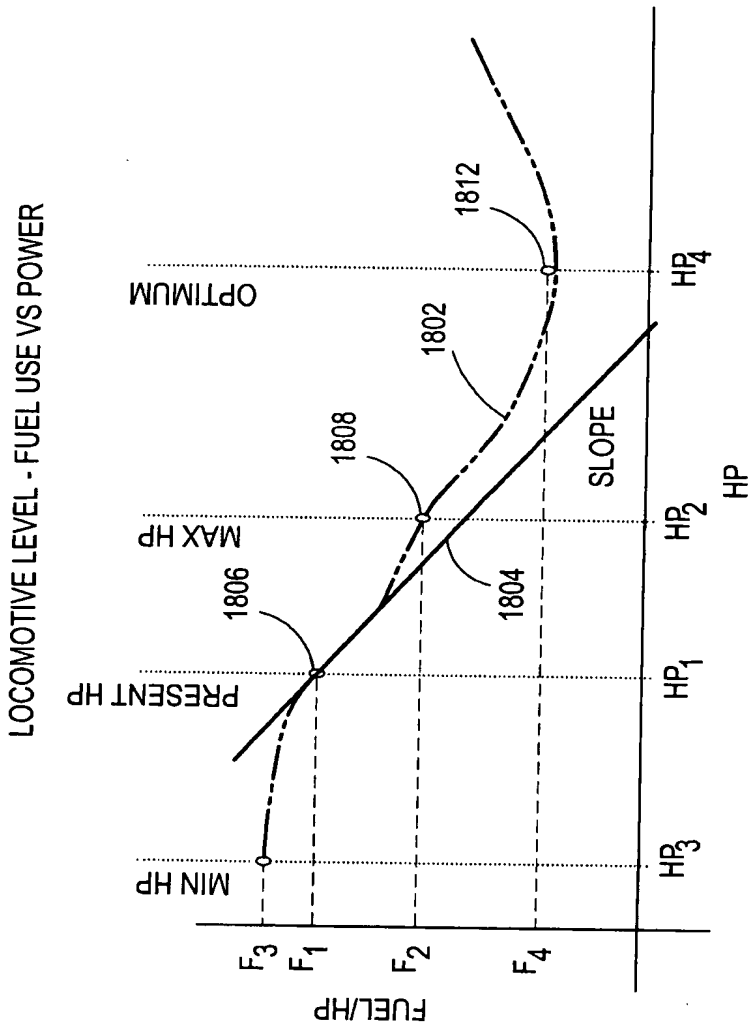

LOCOMOTIVE LEVEL - FUEL USE VS POWER
OPTIMUM
MAX HP
PRESENT HP
MIN HP
1812
1802
1808
1806
1804
SLOPE
HP
FUEL/HP
HP_4
HP_2
HP_1
HP_3
F_3
F_1
F_2
F_4

FIG. 19

LOCOMOTIVE LEVEL OPTIMIZATION - LOSSES VS DC LINK VOLTAGE

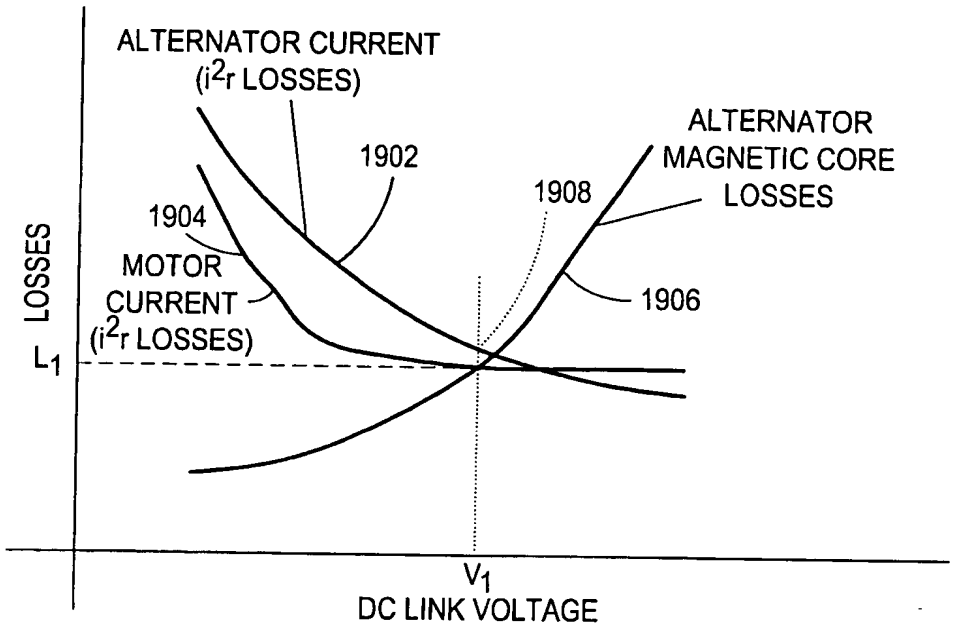


FIG. 20

LOCOMOTIVE LEVEL OPTIMIZATION - FUEL USAGE VS ENGINE SPEED

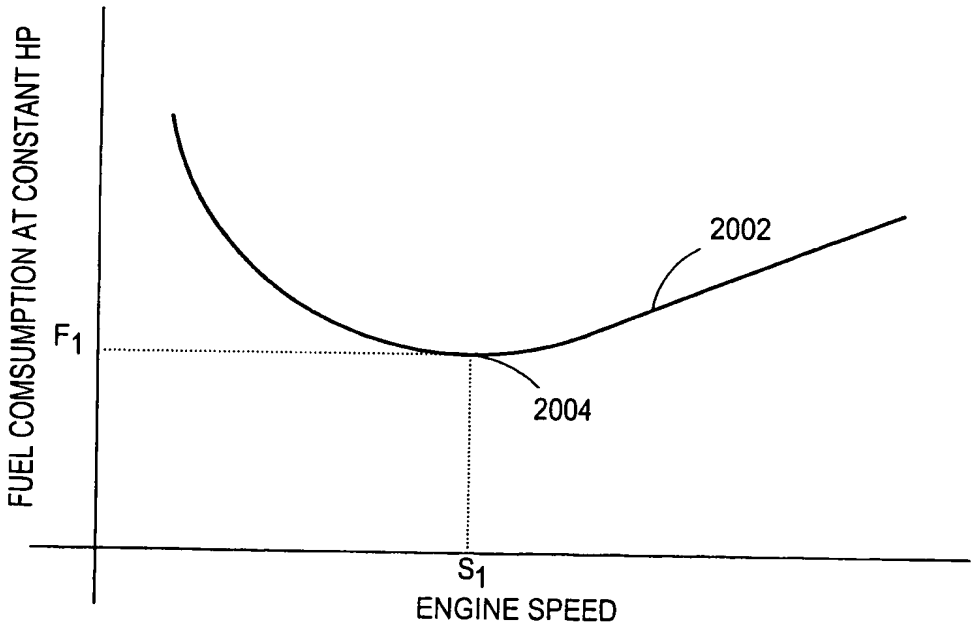
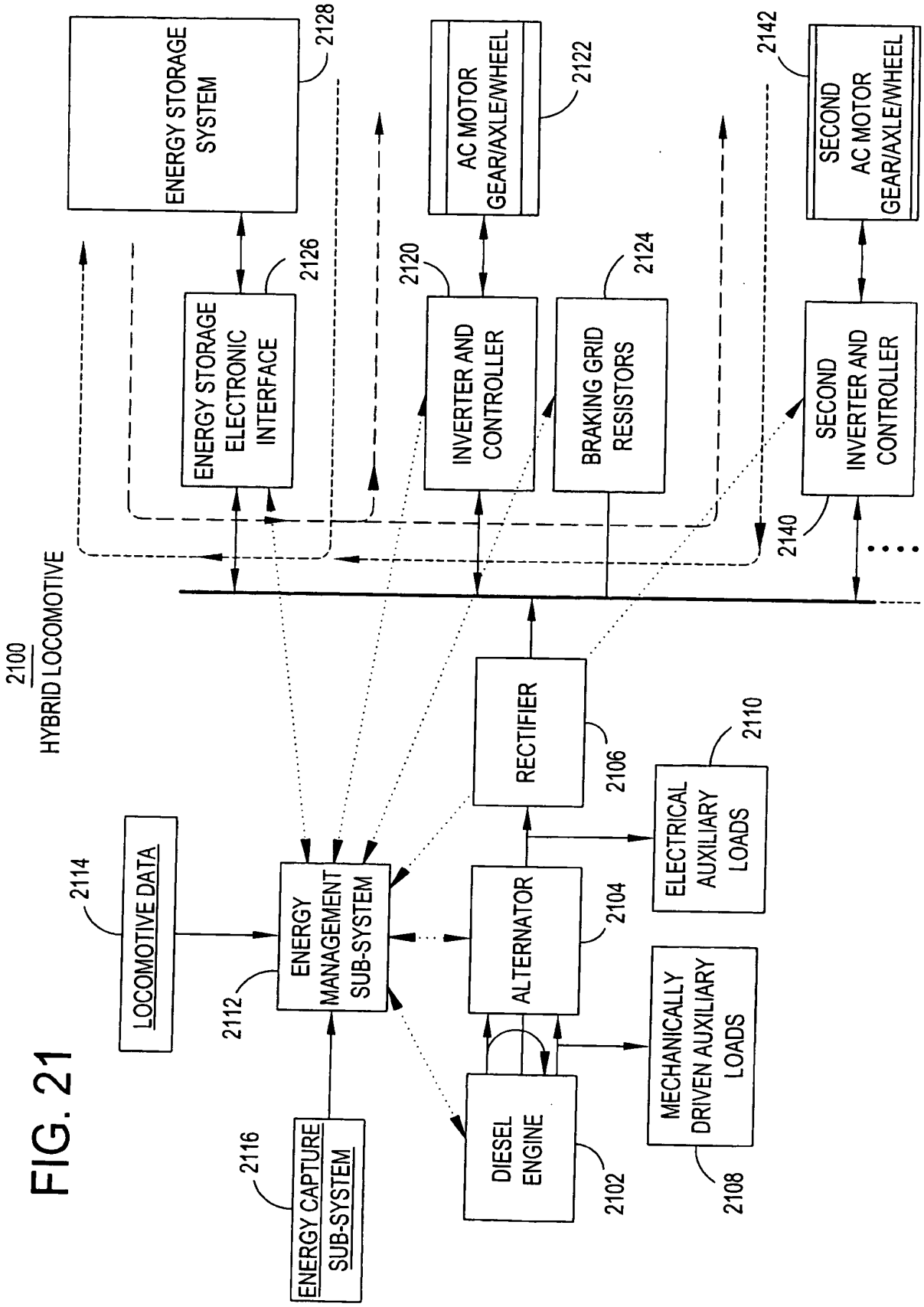


FIG. 21


2100
HYBRID LOCOMOTIVE
ENERGY STORAGE SYSTEM
2128
ENERGY STORAGE ELECTRONIC INTERFACE
2126
AC MOTOR GEAR/AXLE/WHEEL
2122
INVERTER AND CONTROLLER
2120
BRAKING GRID RESISTORS
2124
2142
SECOND AC MOTOR GEAR/AXLE/WHEEL
SECOND INVERTER AND CONTROLLER
2140
RECTIFIER
2106
ELECTRICAL AUXILIARY LOADS
2110
LOCOMOTIVE DATA
2114
ENERGY MANAGEMENT SUB-SYSTEM
2112
ALTERNATOR
2104
MECHANICALLY DRIVEN AUXILIARY LOADS
2108
DIESEL ENGINE
2102
ENERGY CAPTURE SUB-SYSTEM
2116